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14. ABSTRACT
The aim of this project was to establish instrumentation to record honey bee foraging behavior through a Radio-Frequency Identification (RFID) monitoring and to train students in the use of this technology and in the science underlying honey bee behavior. This enables basic scientific advances in how honey bees adapt behaviorally to different stressors. Most notably, it will examine how early life stress and disease lead to later health outcomes in life and how low stress exposure acts to enhance later stress resistance and life outcomes. It will also facilitate the assessment of the social connectivity of individual bees, thought to be a key aspect of stress adaptation. In addition

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Olav Rueppell
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Report Title

Final Report: "Social and Behavioral Science: Monitoring Social Foraging Behavior in a Biological Model System"

ABSTRACT

The aim of this project was to establish instrumentation to record honey bee foraging behavior through a Radio-Frequency Identification (RFID) monitoring and to train students in the use of this technology and in the science underlying honey bee behavior. This enables basic scientific advances in how honey bees adapt behaviorally to different stressors. Most notably, it will examine how early life stress and disease lead to later health outcomes in life and how low stress exposure acts to enhance later stress resistance and life outcomes. It will also facilitate the assessment of the social connectivity of individual bees, thought to be a key aspect of stress adaptation. In addition, it's important to note that food security for human populations depends on pollination achieved to a large extent through honey bee populations, which are currently at risk. Consequently, this research facilitates our understanding of the extent of those risks and the dynamics underlying them.

The Radio Frequency Identification (RFID) technology that was used in this project makes automated recordings of honey bee foraging behavior possible and generates further basic scientific insight on honey bee health. This is a major step forward over typical approaches to studying honey bees in which thousands of data points through observation were obtained, cleaned, and processed. This prior technology has demonstrated known inaccuracies. In contrast, the RFID equipment involves computerized recording and analysis, generating higher accuracy and more rapid analytic throughput. The result will enable better estimations of stress and stress adaptation by honey bee populations and reveal new insights on the social dynamics in a resource-dependent population. These results could be generalizable to other social populations (including humans). An interesting relation between honey bee groups and human groups is the stratification (i.e., caste system) that characterizes both and leads to some actors in the groups being more susceptible to disease and other risks. The RFID technology enables tagging insects with transponders that can detect millimeter-level spatial adjustments to track movements (both individual and groups).

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

RUEPPELL, O., The Dynamics of Israeli Acute Paralysis Virus in Honey Bees. North American Pollinator Protection Campaign Conference, Riverdale, MD.

RUEPPELL, O. The Potential for Multi-Trait Selection in the Honey Bee. 7th Eurbee Meeting, Cluj, Romania.

Number of Presentations: 2.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Nothing to report.

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Carlos Vega-Melendez	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Esmaeil Amiri	0.00
FTE Equivalent:	**0.00**
Total Number:	**1**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Olav Rueppell	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED	Discipline
Greg Seddon	0.00	
Babak Yousefi	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**2**	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

The RFID system was successfully purchased and installed to monitor foraging behavior of individual honey bees. Hardware adjustments were made to optimize reader positioning by 3D-printing custom holders. Proof-of-principle studies have been performed but main experiments with established set up will follow for years to come.

Technology Transfer

Nothing to report yet.

Statement of the problem studied

Experimental systems to study how complex social behavior in groups changes with stress and pathogen exposure are virtually non-existent. The honey bee, *Apis mellifera*, is an excellenet model to address such questions but lifetime recordings of behavior are very labor-intensive. Automation increases the data quality and quantity of such experiments. Therefore, the establishment of a Radio-Frequency IDentification (RFID) system to monitor foraging behavior in honey bees was proposed. Additionally, foraging monitoring of honey bees can help us to understand the phenomenon of declining honey bee health (Perry et al., 2015).

Summary of the most important results

The RFID system to be used was selected from a reliable source in Germany (Heidinger et al., 2014) and it was shipped and installed. Custom modifications were made to obtain better read-out and to ensure the stability of the system. The system was tested and found fully operational for the next experimental season in Spring and Summer 2017.

Bibliography

Heidinger, I. M. M., Meixner, M. D., Berg, S., Büchler, R., 2014. Observation of the Mating Behavior of Honey Bee (*Apis mellifera* L.) Queens Using Radio-Frequency Identification (RFID): Factors Influencing the Duration and Frequency of Nuptial Flights. Insects 5, 513-527.

Perry, C. J., Søvik, E., Myerscough, M. R., Barron, A. B., 2015. Rapid behavioral maturation accelerates failure of stressed honey bee colonies. Proceedings of the National Academy of Sciences 12. 3427–3432.

Appendixes

None.